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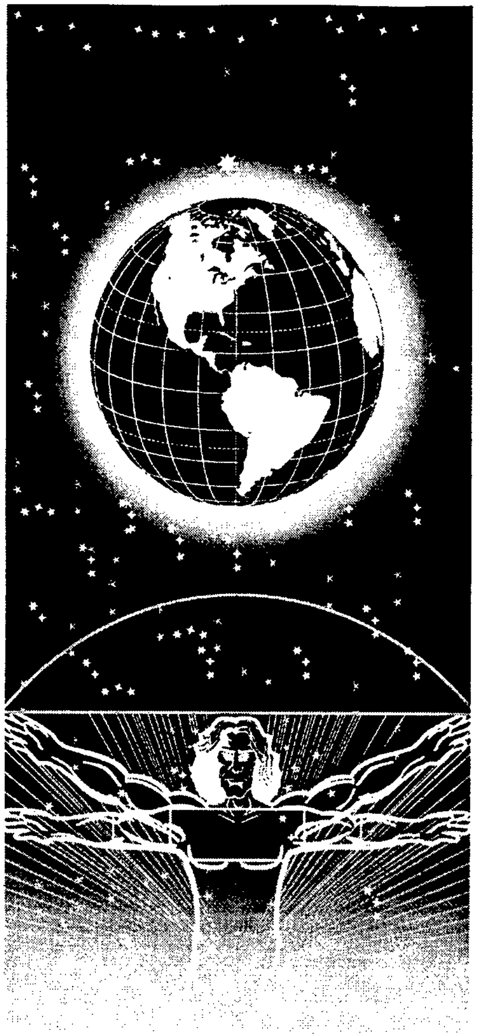

# UNITED STATES AIR FORCE ARMSTRONG LABORATORY

# THE BASIC FIGHTER MANEUVER VISUALIZATION TRAINER


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Initial basic fighter maneuver training methods traditionally involve classroom academics where instructor pilots demonstrate flight maneuvers with their hands. While this method is effective, it requires the pilots to mentally transfer themselves into the actual cockpit environment. This paper describes the development of a virtual environment (VE) for teaching student pilots how to perform basic fighter maneuvers. The Basic Fighter Maneuver Visualization Trainer has the capability to display pre-recorded flight paths from Distributed Interactive Simulation (DIS)-compliant simulator data in a Digital Terrain Elevation Data (DTED) virtual environment database. This portable VE system uses commercially available equipment and software for training at the squadron level. HyperText Markup Language (HTML), the language of the Internet, is used to create a user-friendly, icon-driven, visual interface for program instruction and execution of the virtual flight maneuver demonstrations. The system allows novice pilots to observe, in a helmet-mounted display (HMD), pre-recorded flight maneuvers as performed by experienced pilots before attempting to perform the maneuvers themselves. After demonstrating the learned maneuvers in a DIS-compatible simulator, the novice pilot can again review the pre-recorded demonstrations or view their own recordings by simply loading a DIS tape into the VE training system.

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# PREFACE

This effort documents work conducted under Contract F41624-95-C-5011 by Hughes Training, Inc., Training Operations, at Armstrong Laboratory's Aircrew Training Research Division (AL/HRA) located in Mesa, AZ. This paper describes the development of a virtual environment for teaching student pilots how to perform basic fighter maneuvers. The paper was published in the Proceedings of the 18th Interservice/Industry Training Systems and Education Conference which was held in Orlando, FL from 2-4 December 1996.

This effort was conducted under Work Unit 1123-B2-22, Virtual Environment Training Research. The principal investigator for this work unit was Dr Richard A. Thurman.

# THE BASIC FIGHTER MANEUVER VISUALIZATION TRAINER

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## INTRODUCTION

Current fighter maneuver training methods primarily consist of classroom academics where instructor pilots lecture while using their hands or "aircraft models on sticks" to demonstrate the flight maneuvers to be performed. Although this method is effective, it requires the pilots to mentally transfer themselves into a cockpit environment in order to visualize the flight maneuvers. Because of the pilot's natural tendency to use visualization techniques, synthetic or virtual environment (VE) technology was the medium of choice for the development of this training system. The Basic Fighter Maneuver (BFM) Visualization Trainer uses interactive and immersive technologies to provide a deployable, squadron-level training system designed to augment traditional classroom instruction.

The BFM trainer capitalizes on the concept of an "Electronic Classroom" by providing supplemental fighter fundamentals training to the student pilot. After basic fighter concepts are introduced by an Instructor Pilot (IP), the BFM trainer provides the student pilots with an opportunity to take their education into their own hands by providing additional instruction based upon their individual needs and ability to learn. The system allows the student pilot to interactively explore fighter concepts and experience real-time flight maneuver demonstrations. Unlike traditional classroom instruction, the BFM trainer may be made available after-hours, both day and night, so the student always has the opportunity to learn.

The Basic Fighter Maneuver Visualization Trainer uses commercially available equipment and software to provide a low-cost, portable training device allowing the student pilot to observe either pre-recorded flight maneuvers flown by experienced pilots or their own flight maneuvers in a virtual world environment (Figure 1).

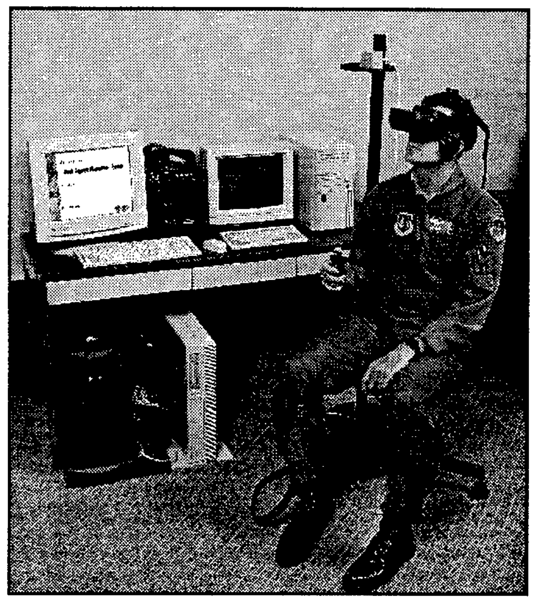


*Figure 1. The Basic Fighter Maneuver Visualization Trainer System Configuration*

The trainer has the capability to display pre-recorded flight paths from Distributed Interactive Simulation (DIS)-compliant simulator data. For example, after completing a practice flight in a DIS-compatible simulator, the student pilot can review the recording by simply loading a 4mm DIS tape into the system. The rational for developing DIS compliance in the BFM trainer was two fold: (1) simulators are rapidly becoming DIS compliant making a wide range of systems available for flight recording, and (2) simulators provide a natural interface to the pilot community by allowing pilots to practice and record sessions in a natural environment. The trainer also allows the student to examine the flight maneuvers from different points of observation, either attached to the aircraft or outside the aircraft.

By design, the BFM Visualization Trainer offers a tremendous advantage over the more traditional training methods by immersing the student pilot in a synthetic flight environment rather than requiring them to mentally transfer themselves in order to visualize the flight maneuvers to be performed.

## USE OF VE TECHNOLOGY FOR PILOT TRAINING

Although Virtual Environment (VE) technology is quickly growing with many potential benefits, it is in essence, just another type of simulation. While simulations in general are designed to "fool" the users' senses into believing they are seeing and experiencing something they are not, VE simulations employ more of the human sensory system to accomplish this (Lane, Kennedy & Jones,1994). In most cases, visual, auditory and tactical devices serve as an interface between the user and the synthetic environment with the quality of the VE experience dependent upon the sophistication of system hardware (Bailey & Witmer, 1994). To a great extent, much VE research and development has been directed towards improving equipment performance and the overall technical capability of the equipment configurations. However, several studies have been conducted to examine the use of virtual environment technologies for increasing pilot performance. In one such study, Hettinger, Nelson, & Haas (1994) gave an indication that pilot performance and situation awareness (the momentary state of knowledge about the elements of one's environment) are generally superior when VE technologies are used when compared to the more conventional technologies. Although the statistical differences in this study were marginally significant at best, the results might suggest that incorporating virtual environment technology ... may offer a number of human performance advantages (Hettinger, Nelson, & Haas, 1994). Hettinger et al. believe that if pilots receive training using advanced technologies, their performance could exceed that in the traditional setting by substantial amounts.

Another study, at the Aircrew Training Research Division of the Armstrong Laboratory in Mesa, AZ, was conducted to determine the differences in pilot performance when flying air intercepts following feedback as presented through three display formats: 2D orthographic, 3D perspective as presented on a monitor, and 3D VE presented through a helmet-mounted display (HMD) (Mowafy & Thurman, 1993). Mowafy and Thurman found that the pilots were enthusiastic about the VE-based instructional techniques. The researchers felt the results "indicated that the 3D stereoscopic virtual reality ... can enhance the environment for training novice pilots to visualize large-scale, three-dimensional spatial relationships.

As VE technology matures, it will become increasingly important to consider the nature of the VE application and define the objectives to be accomplished. VE training systems need to be designed for intended use and not always driven by the novelty of the technology. VE technology should only be used when its immersive and interactive qualities offer advantages over the more traditional training methods as was the case with the Basic Fighter Maneuver Trainer.

## PROJECT DEVELOPMENT

The goal in developing the project was to create a stand-alone, VE training system with an HTML multimedia front-end integrated on a single platform. In addition, the system had to be implemented on low-cost, commercially available equipment that could be deployed at various training squadrons. Instead of using the formidable command line interfaces typical of workstations, HyperText Markup Language (HTML), the language of Internet, was used to create a cross-platform compatible, user-friendly, icon-driven, visual interface (Figure 2). This unique application of HTML technology was used to provide both program instruction and to launch the real-time flight maneuver demonstrations.

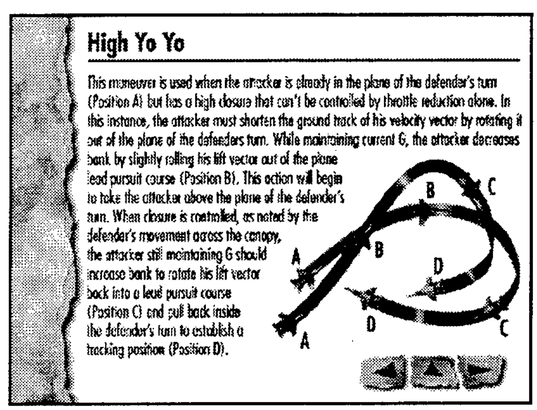



*Figure 2. The HTML Multimedia Interface Provides Program Instruction*

The system was designed to interface with the Armstrong Laboratory's real-time mission planning and support system for training research on networked simulators, the Mission Support System (MSS). Distributed Interactive Simulation (DIS) standard protocol units are used to communicate with the MSS.

The BFM trainer was first developed on a Silicon Graphics, Inc. (SGI) Onyx Reality Engine Computer using Division's dVS Developer's Toolkit for execution on a more portable platform, the Division ProVision 10 VPX Dual Pipe Stereo VE system which is a modified Hewlett Packard 715 workstation. The dVS Developer's Toolkit is a set of software programs for geometry manipulation with a library of C functions for developing application Actors in the dVS Runtime Environment. The dVS Runtime Environment is a software application consisting of a number of servers (Actors) for the generic functions required by VE applications. These Actors provide dedicated functions such as visualization, 3D audio, collision detection, 3D tracking, and user control.

The pre-recorded DIS data packets contain aircraft state information encoded in the WGS 84, DMA TR 8350.2 world coordinate system. The aircraft variables including longitude, latitude, altitude, roll, pitch and yaw and velocities are derived from these encoded packets. The instantaneous position of the aircraft is calculated from these variables using the DIS Dead Reckoning algorithm. A smoothing algorithm was developed to eliminate the jumpiness associated with the estimation and associated positional errors that are the result of the standard Dead Reckoning algorithm. The DIS flight paths were then attached to commercially available F-16 aircraft models. MultiGen software was used to edit and modify the aircraft models to make them appear more realistic. The software was used to develop a translucent cockpit canopy and create additional levels of detail as needed. The Terrain Conversion Option in MultiGen was used to convert Defense Mapping Agency (DMA) Digital Terrain Elevation Data (DTED) gridded post terrain data into a polygonal graphic database. The terrain database was then generated using MultiGen's Delaunay Algorithm which created triangular polygons to fit the original terrain more efficiently. MultiGen DFAD (Digital Feature Analysis Data) Tools were then used to provide cultural information including aerial, linear and point features for the DTED terrain areas of interest.

Further project development included the use of a Crystal River Acoustetron II to create 3D spatialized sound for playback in the virtual environment. F-16 jet sounds from a CD sound effects library were recorded and sampled with Sound Forge software on a PC. These audio files were then saved as .WAV files for functional playback in the dVS Runtime Environment. A Virtual Research Systems VR4 HMD with a resolution of 248 x 230 was used. This helmet is based on a Liquid Crystal Display (LCD) stereoscopic display with a 48 degree (h) x 36 degree (V) field of view with 100% overlap. The VR4 HMD is equipped with stereophonic headphones for presentation of the 3D spatialized audio. A Polhemus head tracking unit provided the student with unrestricted movement throughout the VE. A 3D mouse gave the user control of the virtual interface for program control, including forward, reverse, pause, and changing of the user's point of observation.

## USE OF THE TRAINER

The Basic Fighter Maneuver Visualization Trainer was developed to provide supplemental fighter fundamentals training to the student pilot through interactivity and immersion -- the principals of virtual environment technology. After receiving classroom instruction from an IP, the student is ready to employ the trainer. To use the system, the student proceeds through an HTML multimedia self-paced tutorial which has a dual purpose: to initialize the equipment and to launch the maneuver demonstrations.

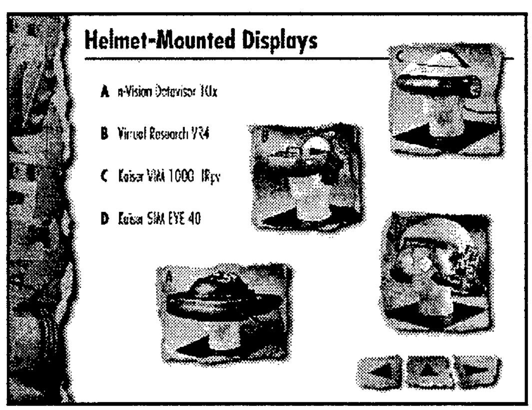
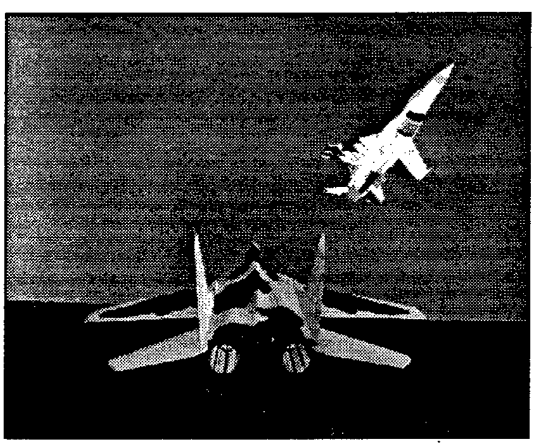



*Figure 3. The HTML Multimedia Interface Is Used To Initialize The Equipment*

The HTML multimedia interface is first used to initialize the equipment including the HMD; it then provides the opportunity to select a terrain database to fly though before presenting formal instruction and diagrams on how to perform the basic fighter maneuvers (Figure 3). After completion of the self-paced HTML tutorial, the student pilot is ready to put on the HMD and experience the real-time flight maneuvers. A series of pre-recorded flight maneuvers performed by expert pilots exist on the trainer and can be reviewed or the trainer can playback a new recording of a flight from a DIS- compliant simulator. If students wish to review their own flight maneuvers, this is done by flying in a DIS-compatible simulator and converting the session's DIS recordings onto 4mm tape. The tape is then inserted into the system and the new flight maneuvers are available to the student for review though the HMD. The student pilot can interact with the synthetic environment by using a 3D mouse input device. An interface which provides user control can be toggled on and off in the VE. After completion of the virtual world experience, the student removes the helmet and may select another flight maneuver to gain experience, re-review any sections in the trainer, or quit the program. If the student pilot wishes to use the system again, he/she may review or skip sections in the trainer in order to go directly to the VE. If the students wish to review their own DIS recordings, they must remember to bring the 4mm tape with them.



*The BFM Virtual Environment*

The BFM trainer with its unique HTML interface and real-time virtual flight maneuvers has been met with great excitement from the Air Force community.

## SUMMARY

In summary, the goal in developing the project was to create a stand-alone VE training system with an HTML multimedia front-end integrated on a single platform to teach student pilots how to perform basic fighter maneuvers. Although it is believed that VE technologies will produce higher levels of performance among pilots (Bailey & Witmer, 1994), VE training systems are still in the early stages of development. Much of the VE research and development has been directed towards improving the technical capability of the equipment configurations rather than determining if skills can be acquired in a VE and then transferred to the real world.

Pilot training curriculum continues to be composed of traditional classroom academics with the delivery of instruction presented by an IP. Research is in progress to determine the advantage of using this type of technology as compared to the more traditional methods for training fighter pilots.

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